Restructuring of Manufacturing Process using Matrix Method: A Case Study

Sudhir Nain, Rajendra. M. Belokar, *Member, IAENG*

Abstract— **In today's world, as competition is increasing in industries, time and cost factors are playing important role. In this paper an attempt has been made to study these factors through matrix method to avoid penalty of any kind. A study was conducted on idler pipe and idler shaft through two case studies with the help of matrix method. The matrix method generates a best sequence with minimum time, minimum cost and reduced penalty. The results are tabulated in the end.**

Index Terms— **Matrix Method, Cellular Manufacturing, Path Matrix Pij, Total Matrix Tij, INR (₹), Group Technology, Cellular Manufacturing, Penalty, Priority**

I. INTRODUCTION

GROUP Technology examines products, parts and assemblies. It then groups similar items to simplify design, manufacturing, purchasing and other business processes. In ungrouped parts it is difficult to see how these parts could be made with the same set of process but when grouped into families, the common processes become more obvious and we can begin to think of a set of machines, tools and skill for each family. Group Technology is the most effective technique available for addressing the variety demanded by today's customers. It allows customization of product with standardization of process [1].

Cellular manufacturing (CM) is a manufacturing philosophy based on group technology (GT), and is seen as a promising solution for the problems faced by the present day manufacturing systems. The formation of a CMS mainly consists of two important tasks: grouping of parts into families on the basis of their similar designs and processing requirements and grouping of machines into cells according to the processing requirements of corresponding part families.

A group of parts can be called as a family if either their processing requirements are similar or they resemble each other in terms of size and geometric shape (Ham et al. [1985] [2], Groover [2008] [3]). Machines in each cell are placed in close proximity to each other thus saving time and cost (handling). Each cell is ideally responsible for the manufacturing of a particular part family which results in simplifying the flow of material and scheduling of the system.

In contrast to Job Shop parts in CM have to travel less distances before their processing is completed. Also, having machines in close proximity the flow of one piece at a time is possible thus saving a lot of waiting time, which is unavoidable in case of Job-Shop manufacturing. Another aspect of CM that causes a reduction in the overall production time is reduced setup times. It is because of the fact that each part family contains parts that have similar design attributes. CM in fact provides a system that has the combined advantages of both Job- Shop and Flow Line Manufacturing. Similar to Job-Shop CMS also utilizes general purpose machines and therefore has the ability to be reconfigured and produce a variety of products. Also, having machines in close proximity in each cell and dedicated to a particular part family efficient flow of material and higher rate of production, like a Flow Line Manufacturing system, can be achieved. Finally it can be concluded that wherever there is a requirement of producing a medium variety of products in medium quantity then CM can prove to be, comparatively, more economical, (Black J. [1983] [4]).

In case where large volumes are to be produced then pure Flow Line Manufacturing is preferable. Similarly, in case where greater varieties of products are to be produced, then pure Job-Shop Manufacturing can be more useful. CM over the years has been gaining popularity. Fry et al [1987] [5] observed that several US based manufacturers adopted CM instead of the conventional Job-Shop Manufacturing. The matrix method results in optimum selection of machine and sequence of operations. The selection and decision process is purely mathematical and is not affected by intuition or rules of thumb [6].

II. MATRIX CONCEPT

The matrix method used in this paper consists of 3 stages:

Stage 1: Technology stage-The Theoretical Process Concept

The output of this stage is the priority and relationship constraints, and the parameters that were used to specify and compute the theoretical operations. Such data are specific for each type of processing and will be used in the transformation stage.

Stage 2: The Transformation Stages-Constructing a Matrix

The left side of matrix draws the operations and some

Manuscript received July 05, 2012.

Sudhir Nain was with Production Engineering, PEC University of Technology, Chandigarh, India, (e-mail: Sudhir.nain350@gmail.com).

Rajendra. M. Belokar, is with, Department of Production Engineering, PEC University of Technology, Chandigarh, India,(corresponding author Phone No.:+91-172-2753287, e-mail, rmbelokar@pec.ac.in).

constraints such as priority (PR) and relationship (REL). On top right side of matrix draw all the candidate resources for each operation are listed. The content of the matrix is Tij, which is the time to perform operation i on resource j.

Stage 3: Decision (Mathematics) Stage

From list of operations to be performed and facilities that are available as per the job requirements, a decision is required to be taken as to which types of machine(s) are to be assigned, and which type of operations are to be performed on these machine(s), what their sequence should be, and what cutting conditions to employ. The optimization criterion is either maximum production or minimum cost. Extra expenses and time should be added to cover extra setup, chucking, transfer of parts between resources, additional complications in capacity planning, job recording, inspection, etc. These extra expenses are called a penalty. Two additional matrixes have formed, known as Zij total matrix and Pij path matrix. Path matrix tells us path of sequence.

III. RESEARCH METHODOLOGY

CASE STUDIES

CASE I

A first study was conducted for manufacturing of idler pipes. Operations done on it firstly cutting of a pipe on band saw machine, after that facing and boring on pipe, and finally welding on pipe was done. The results are tabulated as per the REL, priority and types of operations in the Table1, Table 2, Table3, and Table 4. All machine-operation time, machine-cost, machine operation total matrix, path matrix shown in table below.

Table 1: Machine-Operation Time Matrix

Operation	Priority	REL	M1	M2	M3	M4
010	010	0	2.38	99	99	99
020	020	0	99	1.68	1.52	99
030	030	0	99	3.80	3.52	99
040	040	0	99	99	99	1.04

Table 2: Machine-Operation Cost matrix Cij (multiplying time into relative cost 9.71, 25.57, 26.54, 21.33)

Operation	Priority	REL	M1	M2	M3	M4	Min. Cost
010	010	0	**23.11**	2531.43	2627.45	2111.67	**23.11**
020	020	0	961.3	42.96	**40.34**	2111.67	**40.34**
030	030	0	961.3	97.17	**93.42**	2111.67	**93.42**
040	040	0	961.3	2531.43	2627.45	**22.18**	**22.18**
Total							**179.05**

A. Maximum Production Criterion

This criterion can be explained with following example: Suppose a quantity of 1000 pipes ordered, and the setup times for a machine 40. The penalty for transferring job from one machine to another is 40/1000=0.04.

B. Minimum Cost Criteria

This criterion can be explained with following example: Suppose a quantity of 1000 pipes ordered, and setup cost and other expenses to machine the batch is 90.Thus a penalty for transferring job from one machine to another is 90/1000=0.09.

Operation 3 on machine 1
$S1=961.3+961.3+0=1922.6$
$S2=961.3+2531.43+0.09=3492.82$
$S3=961.3+2627.45+0.09=3588.84$
$S4=961.3+22.18+0.09=983.57$

The minimum value of S is 983.57 and is on transfer to machine 4. Therefore Z31=983.57 and P31=4. Similarly all values calculated and two additional matrices built: Total Matrix Zij and the path matrix Pij,

Table 3: Machine-Operation Total Matrix Zij

Operation	Priority	REL	M1	M2	M3	M4
010	010	0	**179.23**	2687.55	2783.48	2267.79
020	020	0	1077.08	158.74	**156.03**	2227.45
030	030	0	983.57	119.44	**115.69**	2133.85
040	040	0	961.3	2531.43	2627.45	**22.18**

Table 4: Machine- Operation Path Matrix Pij

Operation	Priority	REL	M1	M2	M3	M4
010	010	0	3	3	3	3
020	020	0	3	3	3	3
030	030	0	4	4	4	4
040	040					

CASE II

A second study was conducted for manufacturing of shaft. Operation done on it firstly by cutting saw machine, then facing, turning, grooving, chamfering and finally milling done. The results are tabulated for machine-operation time, machine-cost, machine operation total matrix, path matrix. These are shown in the Table 5, Table 6, Table 7, and Table 8.

Table 5: Machine-Operation Time Matrix

Operation	Priority	REL	M1	M2	M3	M4
010	010	0	2.04	99	99	99
020	020	0	99	2.86	1.12	99
030	030	0	99	8.34	2.24	99
040	040	0	99	0.86	0.36	99
050	050	0	99	0.20	0.05	99
060	060	0	99	99	99	6.20

Table 6: Machine-Operation Cost matrix Cij (multiplying time into relative cost 9.31, 43.70, 43.98, 38.81)

Operation	Priority	REL	M1	M2	M3	M4	Minimum cost
010	010		**18.99**	4326.3	4354.02	3842.19	**18.99**
020	020	0	921.69	124.98	**49.26**	3842.19	**49.26**
030	030	0	921.69	364.46	**98.52**	3842.19	**98.52**
040	040	0	921.69	37.58	**15.83**	3842.19	**15.83**
050	050	0	921.69	8.74	**2.20**	3842.19	**2.20**
060	060	0	921.69	4326.3	4354.02	**240.62**	**240.62**
Total							**425.42**

A. *Maximum Production Criterion*

This criterion can be explained with following example: suppose a quantity of 1000 shaft ordered, and the setup times for a machine 30. The penalty for transferring job from one machine to another is 30/1000=0.03.

B. *Minimum Cost Criterion*

This criterion can be explained with following example: Suppose a quantity of 1000 shaft ordered, and setup cost and other expenses to machine the batch is 60.Thus a penalty for transferring job from one machine to another is 60/1000=0.06.

Operation 5 on machine 1
S1=921.69+921.69+0=1843.38
S2=921.69+4326.3+0.06=5248.05
S3=921.69+4354.02+0.06=5275.77
S4=921.69+240.62+0.06=1162.37

The minimum value of S is 1162.37 and is on transfer to machine 4.Therefore Z51=1162.37 and P51=4. Similarly all values calculated and two additional matrices built: Total sum Zij is displayed in Table 8, and the path matrix Pij, is displayed in Table 7.

Table 7: Machine- Operation Path Matrix Pij

Operation	Priority	REL	M1	M2	M3	M4
010	010	0	3	3	3	3
020	020	0	3	3	3	3
030	030	0	3	3	3	3
040	040	0	3	3	3	3
050	050	0	4	4	4	4
060	060	0				

Table 8: Machine-Operation Total Matrix Zij

Operation	Priority	REL	M1	M2	M3	M4
010	010	0	**425.54**	4732.85	4760.51	4248.74
020	020	0	1278.98	482.27	**406.49**	4199.48
030	030	0	1180.46	623.23	**357.23**	4100.96
040	040	0	1164.63	280.52	**258.71**	4085.13
050	050	0	1162.37	249.42	**242.88**	4082.81
060	060	0	921.69	4326.3	4354.02	**240.62**

IV. RESULT

Case I

It is concluded that, operation 1 was performed on machine 1 and both operation 2 and 3 were performed on machine 3; operation 4 was performed on machine 4. The results were encouraging. It was found that best sequence generated with matrix method gives us optimum results with minimum time and minimum cost. Best operation sequence with time and cost given in Table 9.

Table 9: The proposed process for manufacturing of idler pipe

Machine	Operation	Cost (₹.)	Time (Minutes)
1	1	23.11	2.38
3	2,3	40.34+93.42 =133.76	3.52+1.52= 5.04
4	4	22.18	1.04

Case II

It is concluded that operation1 was performed on machine 1 and operation 2, 3, 4, and 5 were performed on machine 3, similarly operation 6 was performed on machine 6. It was found that best sequence generated with matrix method gives us optimum results with minimum time and minimum cost. Best operation sequence with time and cost for manufacturing of idler shaft is tabulated in Table 10.

Table 10: The proposed process for manufacturing of idler shaft

Machine	Operation	Cost (₹.)	Time (Minutes)
1	1	18.99	2.04
3	2, 3, 4, 5	49.26+98.52+15.83+2.20 = 165.81	1.12+2.24+0.36+0.05 =3.77
4	6	240.62	6.02

V. CONCLUSION

It is concluded that in Case I, it is possible to reduce 1 transfer penalty (job changeover time from one machine to another) by doing both operation 2, 3 on machine 3. In Case II, it is possible to reduce 3 transfer penalties by doing operation 2, 3, 4, 5 on machine 3.

Finally sequence of manufacturing with minimum time and minimum cost was generated.

VI. FUTURE SCOPE

In Case I, operations 1, 4 in was done on machine 1 and machine 4 only. Operations 1 and 6 in Case II were done on machine 1 and machine 4.this needs to be explored further to assigned more available machines, thereby effective utilization of these machines increases.

More study can be explore in this method, that can be applied to a problem where all machines can be assigned do all operations without any constraints.

REFERENCES

[1] Introduction to GT and GT AND Manufacturing, 2012 retrieved from www.strategosinc.com.

[2] Ham, I. Hitomi, K. & Yoshida, T., 1985, “Layout Planning for Group Technology In Group Technology”. Applications to Production Management, 153-169.

[3] Groover, M.P., 2008, “Automation Production System and Computer Integrated Manufacturing”, Prentice Hall, New Jersey, USA.

[4] Black, J. ,1983,“Cellular Manufacturing Systems Reduce Setup Time, Make Small Lot Production Economical”. Industrial Engineering, 36-48.

[5] Fry, T. Breen, M. & Wilson, M. ,1987, “A Successful Implementation of Group Technology & Cellular Manufacturing”. Production & Inventory Management Journal, 28(3): 4-6.

[6] Gideon Halevi,1998, “Restructuring the manufacturing process applying the matrix method”, by CRC Press.